

# INTERCOMPARISONS OF GOES-DERIVED CLOUD PARAMETERS AND SURFACE OBSERVATIONS OVER SAN NICOLAS ISLAND

P. Minnis  
Atmospheric Sciences Division, NASA Langley Research Center  
Hampton, Virginia 23665-5225

C. W. Fairall  
Department of Meteorology, Pennsylvania State University  
University Park, Pennsylvania 16802

D. F. Young  
Aerospace Technologies Division, Planning Research Corporation  
Hampton, Virginia 23666

## 1. Introduction

The spatial sampling limitations of surface measurement systems necessitate the use of satellite data for the investigation of large-scale cloud processes. Understanding the information contained in the satellite-observed radiances, however, requires a connection between the remotely sensed cloud properties and those more directly observed within the troposphere. Surface measurements taken during the First ISCCP Regional Experiment (FIRE) Marine Stratocumulus Intensive Field Observations (IFO) are compared here to cloud properties determined from Geostationary Operational Environmental Satellite (GOES) data in order to determine how well the island measurements represent larger areas and to verify some of the satellite-measured parameters.

## 2. Data

Total cloud amounts and visible ( $0.65 \mu\text{m}$ ) top-of-the-atmosphere cloud albedos were derived with the hybrid bispectral threshold method (HBTM; Minnis et al., 1987) from hourly GOES-West data (Young et al., 1989) over two  $0.5^\circ$  regions between  $119^\circ\text{W}$  and  $120^\circ\text{W}$  and  $33^\circ\text{N}$  and  $33.5^\circ\text{N}$  for July 1-19, 1987. Cloud albedos, cloud fractions, and integrated cloud liquid water contents were determined from measurements taken nearly continuously over San Nicolas Island (Fairall et al., 1989) with a variety of instrumentation during this same time period. San Nicolas Island (SNI) is located near the center of the east-west boundary of two satellite regions. Results from both the microwave and solar radiometer cloud liquid water content (LWC) measurements are compared to the satellite albedos. These preliminary comparisons match relatively large areal averages to essentially linear averages of the cloud fields advecting over a fixed point.

## 3. Results and Discussion

Mean hourly cloud fractions are shown in Fig. 1 for the SNI and HBTM results. The SNI cloud amounts, on average, are  $0.045 \pm 0.076$  greater than the HBTM total cloud amounts. The diurnal variations are similar with early morning maxima and late afternoon or evening minima. The HBTM diurnal range, however, is 0.50 compared to 0.30 for the SNI data. Peak cloud cover occurs ~ 1 hour earlier for the HBTM results. The differences in the cloud amounts may arise for several reasons. Cloud cover over the island may not be representative of the larger area. Since the clouds generally

pass over the island, there may be some surface heating during the day which affects the cloud deck. During the night, the local heating ceases. Radiative cooling of the island is limited by the large-scale cloud field so that there should be little island effect at night. Sampling differences may also affect the comparison. A visual examination of the data using the video imagery developed by D. Wylie and P. Grimm (University of Wisconsin, unpublished, 1988) revealed that of the 19 days, the cloud cover over the island and surrounding regions appeared to vary the same during only 7 days. During 5 of the days, a V-shaped clearing formed around and downwind of the island during the afternoon. During another 5 days, the regions surrounding the island showed considerable clearing while a strip centered on the island remained overcast. The clouds cleared around the island and over the island itself during the remaining 2 days, however, the clouds cleared over the island last. In nearly all cases in the imagery, the cloud cover over the island and surrounding regions was very similar at the beginning of each day during the IFO. These visual findings are consistent with the means shown in Fig. 1 and with SNI time series of cloud amount. The HBTM and SNI results show good agreement after midnight until sunrise. Faster and more extensive clearing occurs around the island than over the island itself. This apparent island effect may also be responsible for the differences in satellite and island cloud-top heights observed during the day (Minnis et al., 1989).

A comparison of the satellite visible and SNI broadband shortwave cloud albedos is shown in Fig. 2. The narrowband albedo is considerably lower than the island-derived albedo values. Spectral differences, sampling, and the atmospheric effects included in the satellite results are primarily responsible for the differences. To minimize the spectral differences, the visible albedos were converted to broadband shortwave albedos using an empirical solar-zenith angle dependent ratio. The resulting albedos were then corrected for atmospheric effects using the simple model of Chen and Ohring (1984). Since the clouds are so low, it was assumed that they could be treated like the surface. The resulting cloud albedos derived from those in Fig. 2 are shown in Fig. 3. Cloud albedos were averaged without any weighting by cloud amount for all cases with cloud amounts greater than 10%. The dashed line represents a mirror image of the morning satellite results. It is shown to demonstrate the sizable decrease in cloud albedo during the afternoon. Despite the broadband and atmospheric corrections, the SNI cloud albedos are still higher by ~5% on average. If it is assumed that the SNI clouds are more like those over the surrounding regions when there is more cloudiness, then mean satellite cloud albedos derived by weighting the albedo by the cloud fraction should be more similar to the SNI results than those derived using a simple averaging technique. This approach was implemented with the results shown in Fig. 4. In this instance, the mean cloud albedo differences are only ~ 2% with greater errors near the terminator as expected (Chen and Ohring, 1984). The remaining discrepancies may be due to sampling and technique differences, bidirectional reflectance model biases, and island effects. Though visual examination of albedo is unreliable, the clouds were distinctly brighter over the island than over the adjacent areas during at least 2 days, July 5 and 8. An island effect which results in more cloud cover may also alter the cloud composition relative to the large scale.

The LWC values derived from the SNI microwave and solar measurements are correlated with the satellite visible albedos in Figs. 5 and 6, respectively. Two curves are shown in each figure. The lower curve which levels at an albedo of  $\sim 55\%$  is based on the results of Coakley and Snider (1989). Their regression is

$$1/\rho = 1.74 + 48\mu_0/\text{LWC}, \quad (1)$$

where  $\rho$  is the visible reflectance,  $\mu_0$  is the cosine of the solar zenith angle, and LWC is given in  $\text{gm}^{-2}$ . The second curve shown in these figures is a regression fit to the observed data using the relationship,

$$\ln(1 - \alpha) = a + b\text{LWC}/\mu_0. \quad (2)$$

The cloud albedo is  $\alpha = \rho / \chi$ , where  $\chi$  is an anisotropic reflectance correction factor. The coefficients  $a$  and  $b$  are  $-0.44$  and  $-0.0016$ , respectively, for the microwave data. The coefficients for the solar data are  $a = -0.46$  and  $b = -0.0016$ . The curve for (2) is tangential to the knee of the curve for (1). The latter seems to fit the data well for  $\text{LWC}/\mu_0$

$< 100 \text{ gm}^{-2}$ , but does not provide for any albedos greater than  $\sim 55\%$ . Thus, the curve is unrealistic for higher values of albedo. Equation (2), however, shows no skill for matching the lower albedos, but it allows for additional increases in cloud albedos beyond  $50\%$ . It is concluded, therefore, that a combination of these two functions would provide a more complete representation of the relationship between albedo and LWC. This combination is accomplished by matching the curves at  $\alpha = 45\%$ .

#### 4. Concluding Remarks

It appears that the SNI-observed clouds may be affected by the island. Additional support for this thesis will require analysis of satellite data over a small region centered on the instrument site. Accounting for these potential effects, the satellite-derived cloud amounts and albedos are very similar to those observed over SNI. The diurnal variations in cloud amount and cloud albedo are also comparable to those seen over other areas (e.g., Minnis and Harrison, 1984). These preliminary results have also provided a relationship which may be utilized during the day to determine cloud LWC over other parts of the IFO area.

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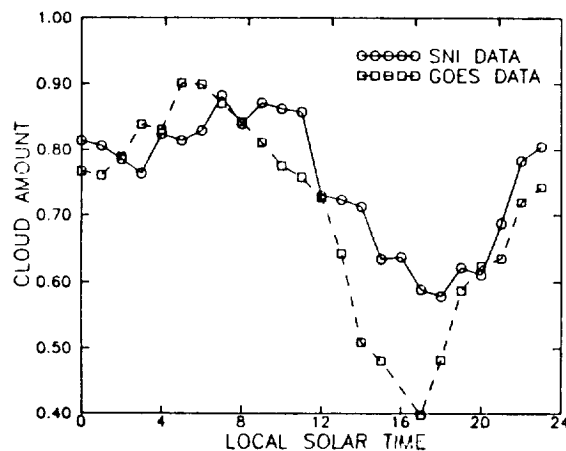


Fig. 1. Mean IFO cloud amounts derived from GOES over a  $0.5^\circ \times 1.0^\circ$  region centered on San Nicolas Island and from island observations.

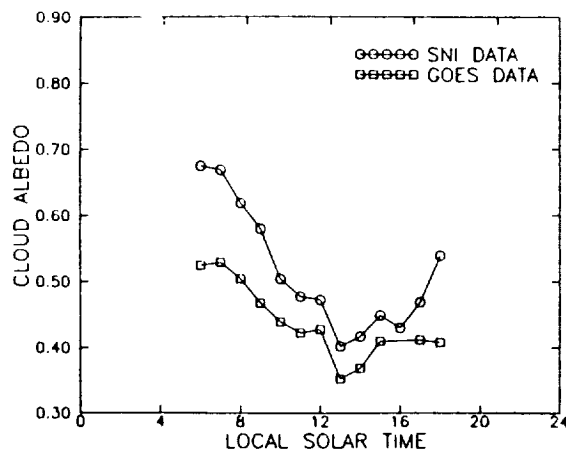


Fig. 2. Same as Fig. 1, except for GOES visible cloud albedos at the top of the atmosphere and island broadband shortwave cloud albedos.

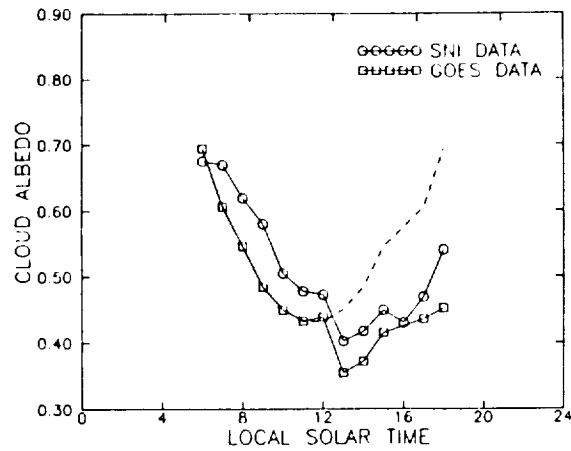


Fig. 3. Same as Fig. 2, except for broadband, atmosphere-corrected GOES cloud albedos.

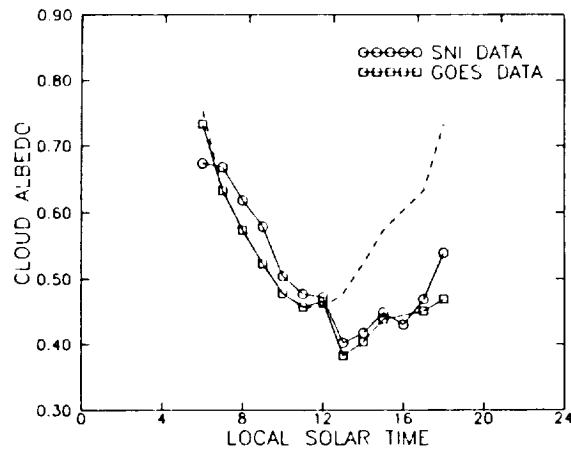


Fig. 4. Same as Fig. 3, except for cloud-amount weighted averaging of GOES cloud albedos.

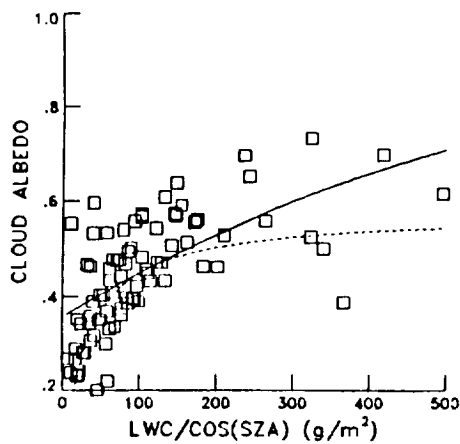


Fig. 5. Correlation of GOES visible cloud albedos and LWC derived from island microwave measurements (see text for discussion of curves).

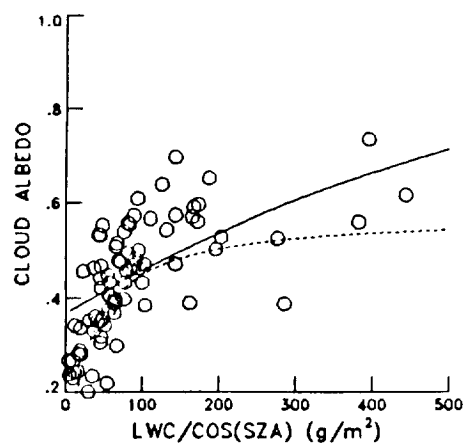


Fig. 6. Correlation of GOES visible cloud albedos and LWC derived from island solar radiation data (see text for discussion of curves).

